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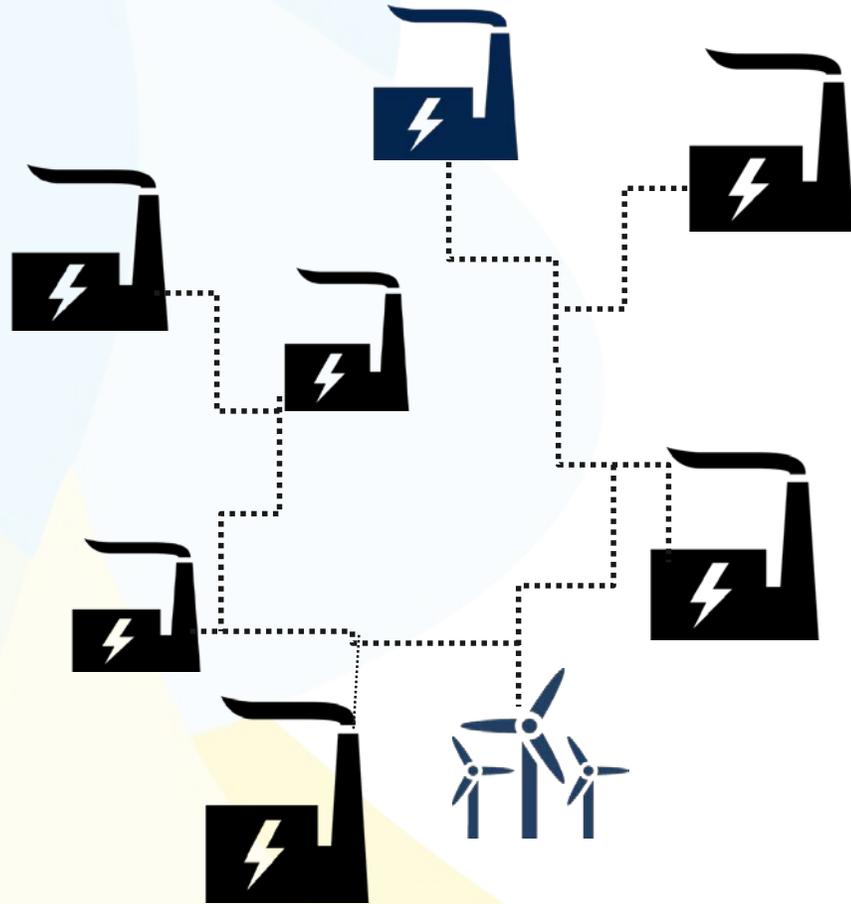
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EMISSIONS VARIATION BY TIME IN CALIFORNIA

May 2018

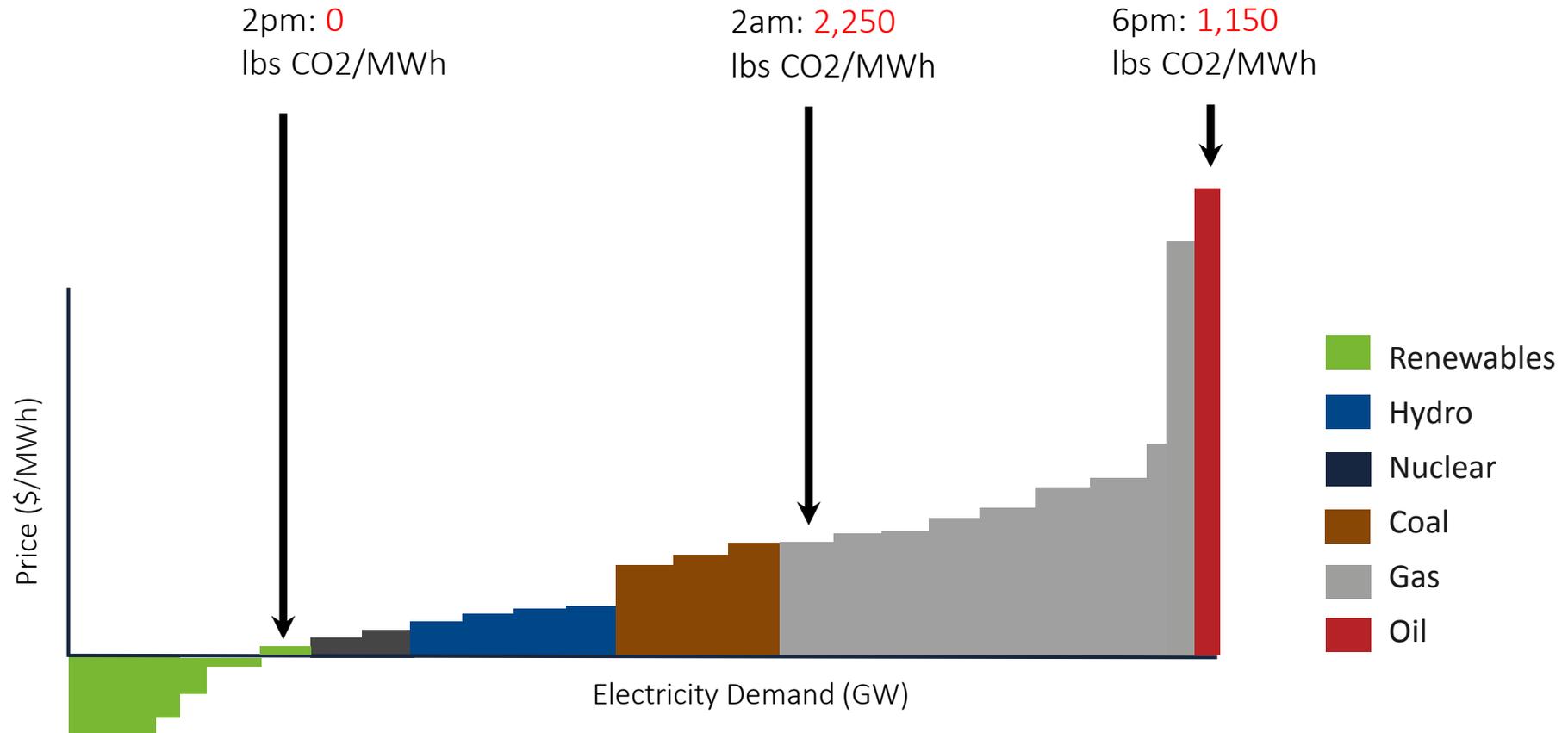


Time-varying emissions measurement has improved dramatically



- Improvements in source data
 - In 2018, the U.S. EPA significantly upgraded hourly coverage of California emissions via the AMPD
- Improvements in software
 - Several organizations (e.g. CAISO and WattTime) now measure emissions in real time
- Improvements in algorithms
 - Over a dozen journal articles published on marginal emissions detection algorithms since 2012
- Improvements in accounting
 - GHGP Scope 2 update

Why emissions factors vary over time (sample grid)



Two ways to measure emissions factors

Average emissions

- Average emissions rate of all power plants that are operating at a given time
- Accurately measures *current* carbon emissions of entire grid
- Excellent properties for carbon accounting
 - Easily verifiable
 - Sum of all individual emissions equals total emissions
- Global standard in **carbon footprinting**

Marginal emissions

- Rate by which emissions will change per additional MWh of electricity used/saved
- Accurately measures *change* in carbon emissions if a change is made
- Excellent properties for decision making
 - Quantifies impact of changes
 - Only way to see which projects would lead to greater *reduction* in total emissions
- Global standard in **avoided emissions calculations**

Average emissions rates over time (California average)

AVERAGE CALIFORNIA WEEKDAY

Month →	1	2	3	4	5	6	7	8	9	10	11	12
Hour ↓	Wday											
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3												
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- CAISO has low average emissions rates by U.S. standards
- SMUD, TID similar, but LADWP significantly higher
- Relatively stable/predictable
 - Strong seasonality
 - Morning, evening ramp (the “duck curve”)
 - Weekends generally lower
- Happy to provide 8760 data as needed

Marginal emissions rates over time (north CAISO)

MARGINAL SOUTHERN CALIFORNIA WEEKDAY

Month →	1	2	3	4	5	6	7	8	9	10	11	12
Hour ↓	Wday											
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- CAISO has exceptionally low marginal emissions rates by U.S. standards
- Variability of California rates rising fastest in the continental U.S.
- *Zero* marginal emissions moments increasingly frequent
- Yet increasingly unpredictable; no hour of the year is consistently zero
- Old pattern: dirtiest at peak
- Current pattern: increasingly flat on average, variable minute-to-minute, some evening ramp
- Coming soon: *cleanest* at peak

Thank You

Gavin McCormick

Executive Director

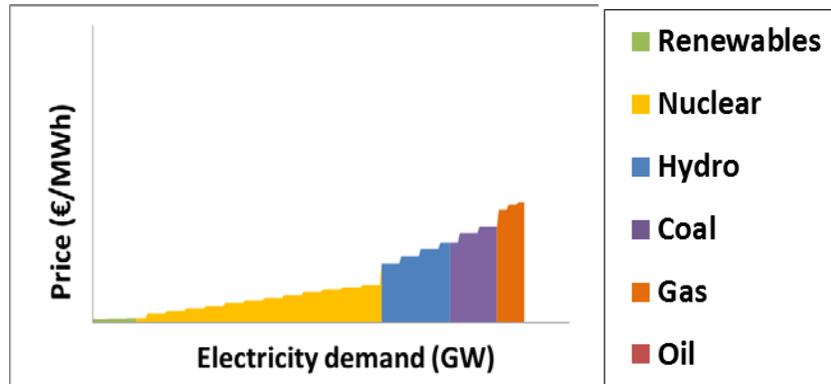
contact@WattTime.org

857.540.3535

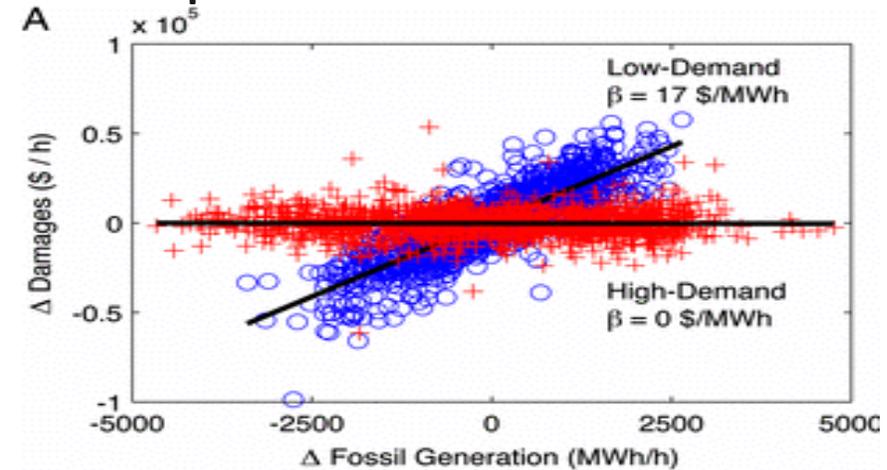


Appendix. Two ways to estimate marginal emissions

Heat-rate method



Empirical method



- There are very different approaches in the published literature to estimate marginal emissions rates
- Theory-based heat rate models vs. statistically based empirical models
- Heat rates models are more precise, while empirical models are more accurate
- However, for seasonal hourly data in California, both approaches return very similar results